QPE Algorithm Update

Bob Kuligowski, NOAA/NESDIS/STAR
Walt Petersen, NASA-MSFC
Nai-Yu Wang, U. Maryland

3rd Annual GOES-R GLM Science Meeting
Huntsville, AL 1-3 December 2010

Outline

- GOES-R Rainfall Rate Algorithm Update
- Walt Petersen's Update
- Nai-Yu Wang's GOES-R3 Work

Rainfall Rate Algorithm Description

- **IR algorithm calibrated in real time using MW rain rates**
  - » IR continuously available, but weaker relationship to rain rate
  - » MW more strongly related to rain rate, but available ~every 3 h
- **Calibration by type and region**
  - » Three cloud types:
    - – "Water cloud": $T_{7.34}<T_{11.2}$ and $T_{8.5}-T_{11.2}<-0.3$
    - – "Ice cloud": $T_{7.34}<T_{11.2}$ and $T_{8.5}-T_{11.2}\geq-0.3$
    - – "Cold-top convective cloud": $T_{7.34}\geq T_{11.2}$
  - » Four geographic regions: 60-30ºS, 30ºS-EQ, EQ-30ºN, 30-60ºN
- **Two retrieval steps:**
  - » Rain / no rain separation via discriminant analysis
  - » Rain rate via multiple linear regression

Rainfall Rate Algorithm Description

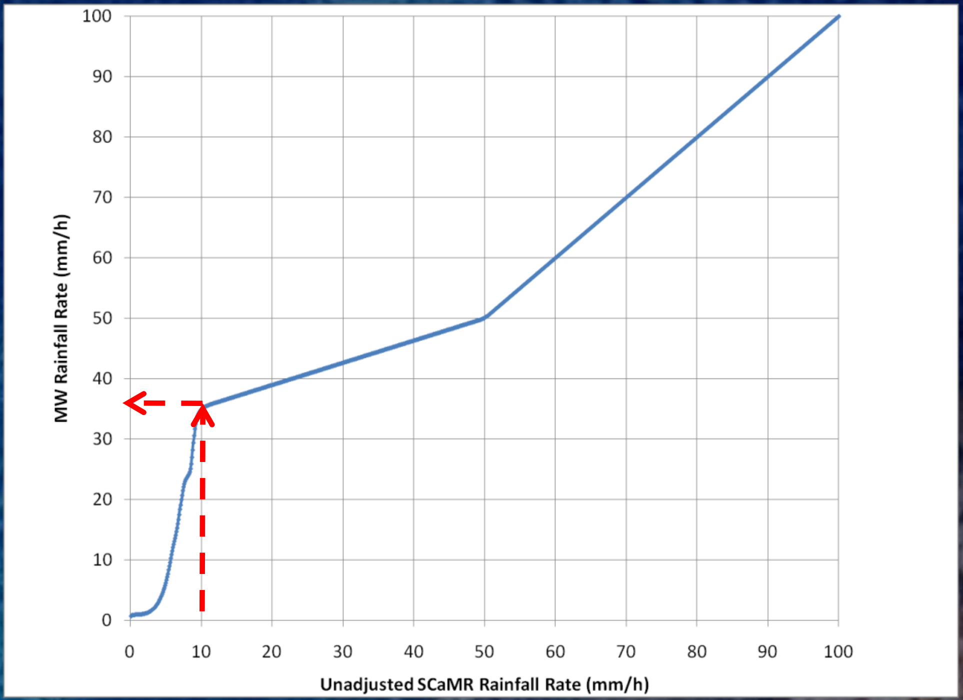
- **8 predictors derived from 5 ABI bands**

$T_{6.19}$	$T_{8.5} - T_{7.34}$
$S = 0.568-(T_{min,11.2}-217\ K)$	$T_{11.2} - T_{7.34}$
$T_{avg,11.2} - T_{min,11.2} - S$	$T_{8.5} - T_{11.2}$
$T_{7.34} - T_{6.19}$	$T_{11.2} - T_{12.3}$

- **8 additional nonlinear predictors**
  - » Regressed against the MW rain rates in log-log space

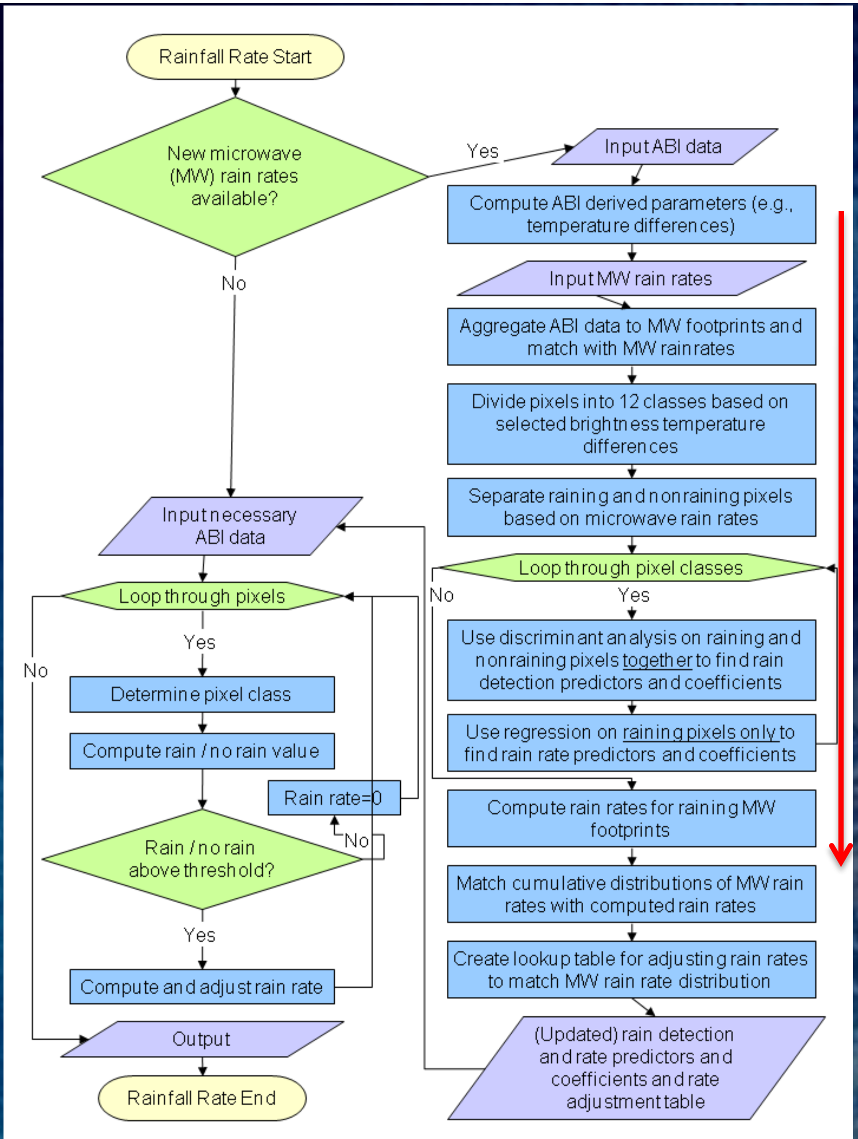
Rainfall Rate Algorithm Description

- **Initial SCaMPR rain rates strongly underestimate heavy rain**
- **Adjust distribution**
  - » For each class and region, match the CDF of the SCaMPR rain rates against the CDF of the target MW rain rates
  - » Create an interpolated LUT to modify the SCaMPR rain rate distribution



Rainfall Rate Algorithm Description

Apply most recent calibration in between new MW overpasses



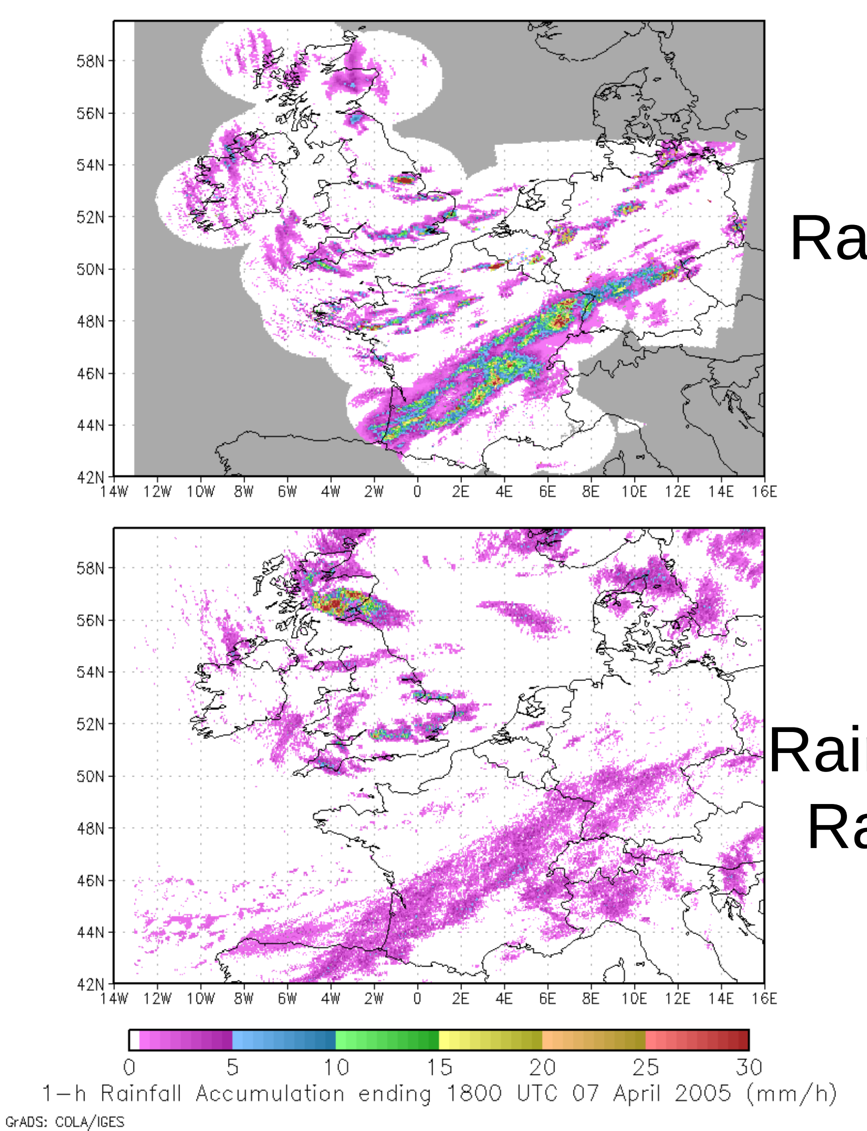
Update calibration when new MW rain rates available

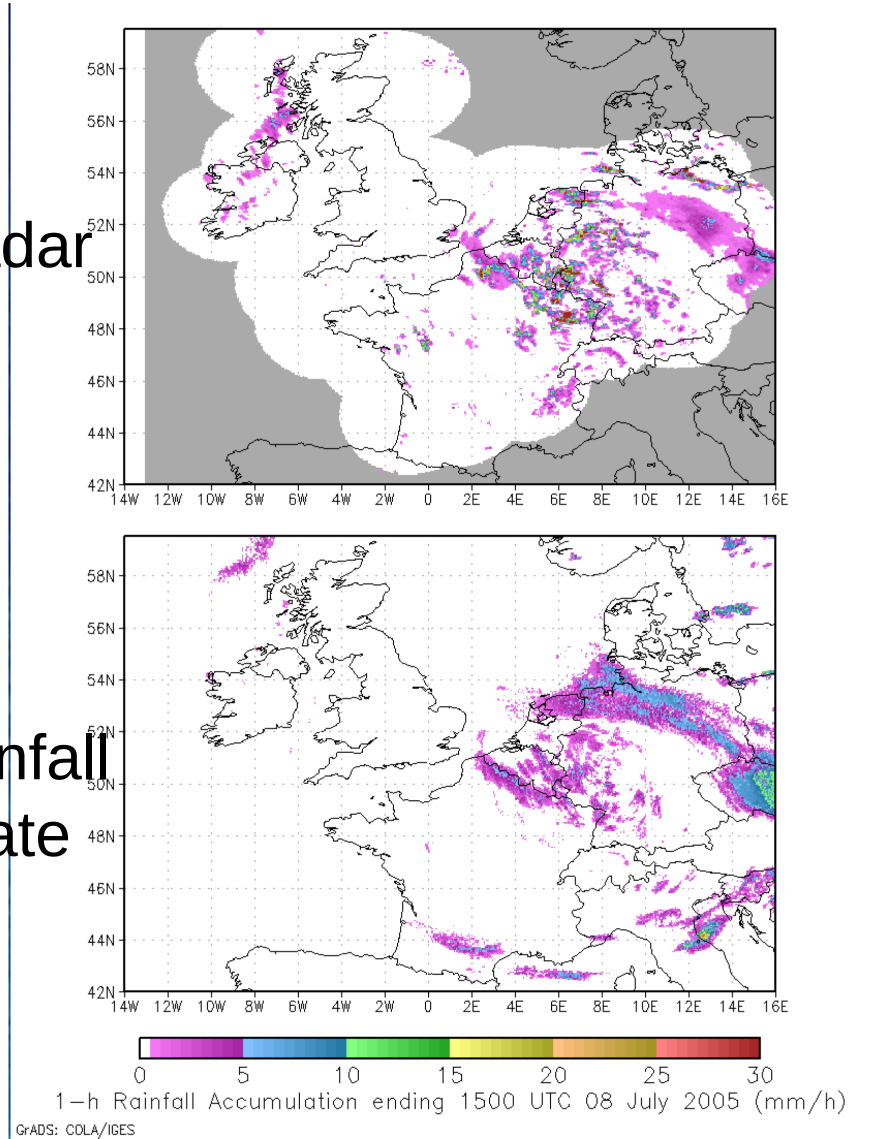
Retrieve rain rates from ABI data

Rainfall Rate Examples

Radar

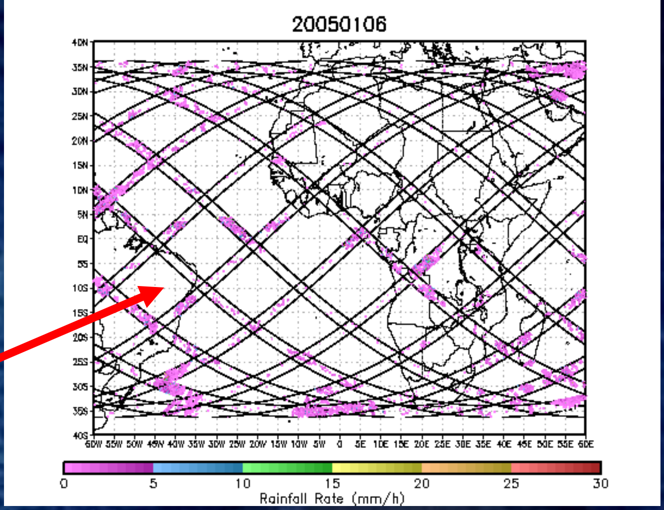
Rainfall Rate

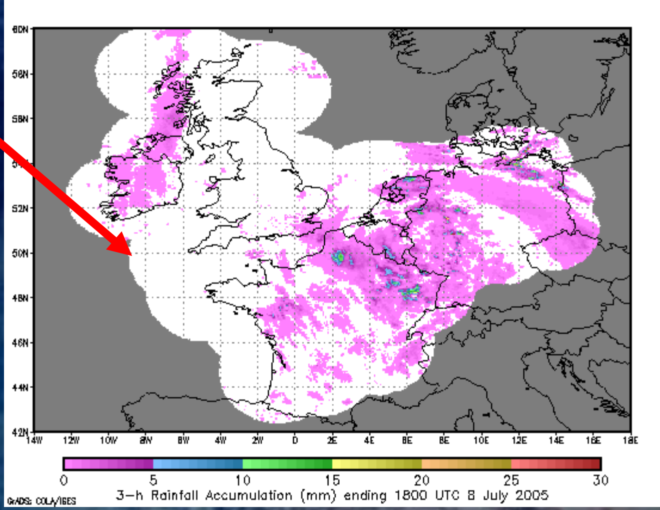




Validation: Truth Data

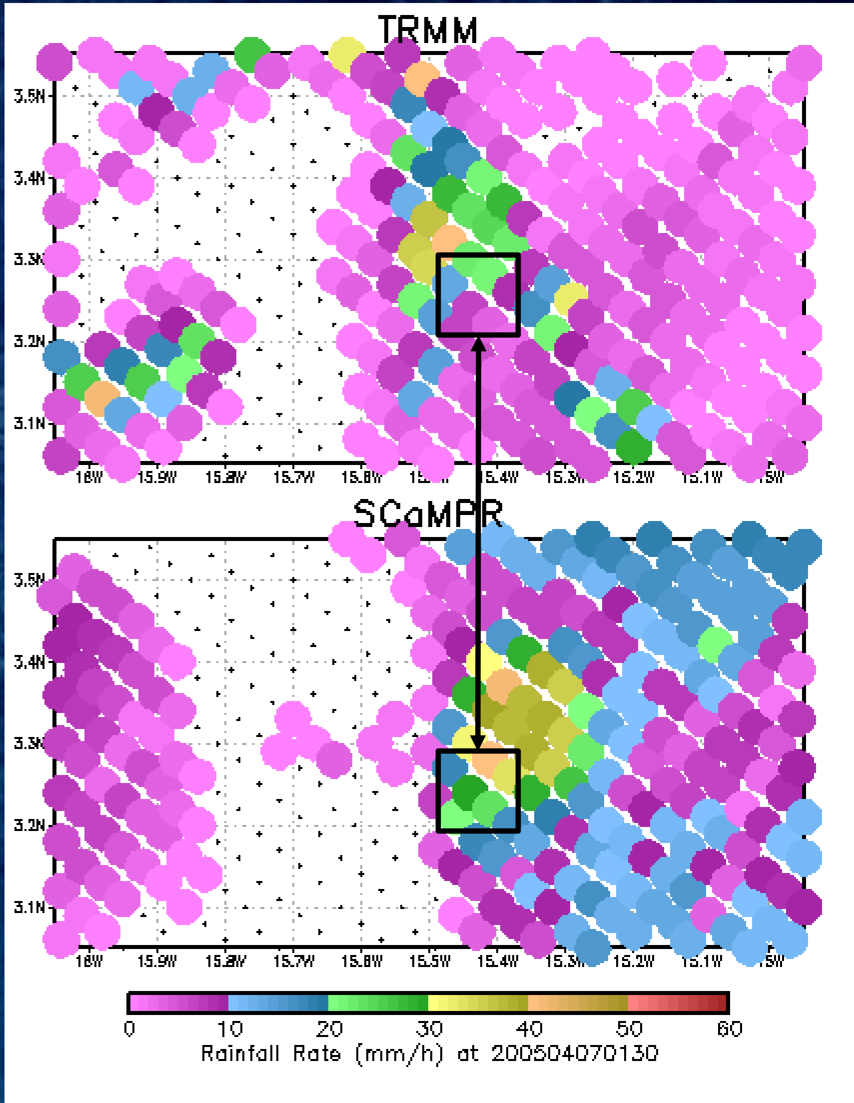
- Time scales ≤3 h, so must validate against radar
- Validation datasets in SEVIRI region:
  - Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar
  - Nimrod radar data from the British Atmospheric Data Centre (BADC)
- Efforts to obtain other radar data have not been successful, but CHUVA is promising.



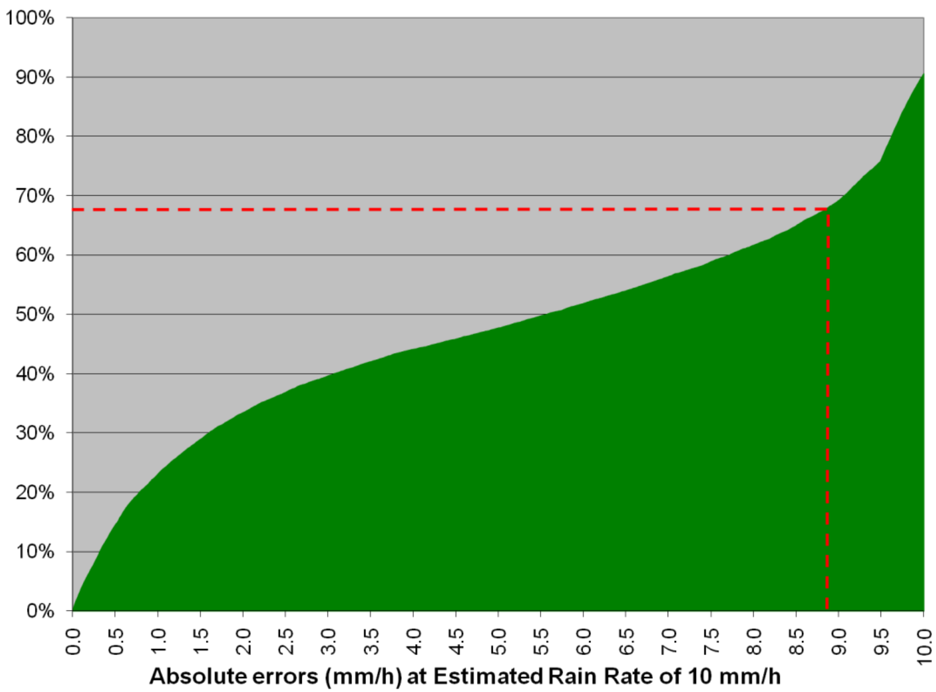


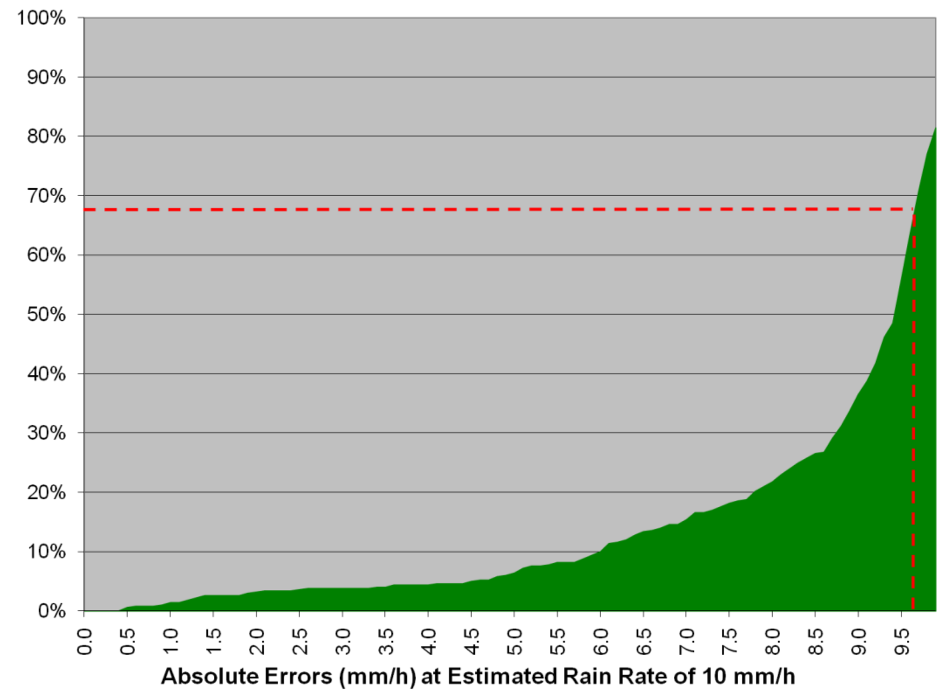
Rainfall Rate "Fuzzy" Validation

- **Pixel-by-pixel comparisons difficult**
  - » Instantaneous rain rate varies too much at small scales
- **Neighborhood comparison**
  - » Compare to most similar nearby value (Ebert 2008)
  - » Better indication of usefulness
  - » Not needed for 3-h Rainfall Potential / Probability



Rainfall Rate Validation





CDF of (absolute) errors of Rainfall Rate pixels with rates of 9.5-10.5 mm/h vs. TRMM PR for 51 days: 6-9 January, April, July, and October 2005.

CDF of (absolute) errors of Rainfall Rate pixels with rates of 9.5-10.5 mm/h vs. NIMROD radar data for 34 days: 6-9 April, July, and October 2005.

Validation Summary vs. Spec

Validation versus TRMM PR for 51 days of data: 6-9 January, April, July, and October 2005 and all of January 2008:

Rainfall Rate (mm/h)	Requirement		vs. TRMM radar	
	Accuracy	Precision	Accuracy	Precision
	6.0	9.0	4.9	8.9

Validation against Nimrod for 6-9 April, July, and October 2005:

Rainfall Rate (mm/h)	Requirement		vs. NIMROD	
	Accuracy	Precision	Accuracy	Precision
	6.0	9.0	8.6	9.7

Status and Future Work

- **Delivered "final" algorithm to System Prime 30 Sep 2011**
- Validation against an additional 4 months of data ongoing
- Developing real-time and "deep-dive" validation tools for further evaluation and potential improvement
- "Maintenance" delivery 30 September 2012 that incorporates feedback from "deep-dive" validation

GLM QPE Guidance for SCaMPR

(W. Petersen, MSFC; A. Leroy, UAH)

Passive Microwave Tuning and Cloud (cell) Characteristics

1) Rainfall Detection and Convective and Stratiform (C/S) Precipitation

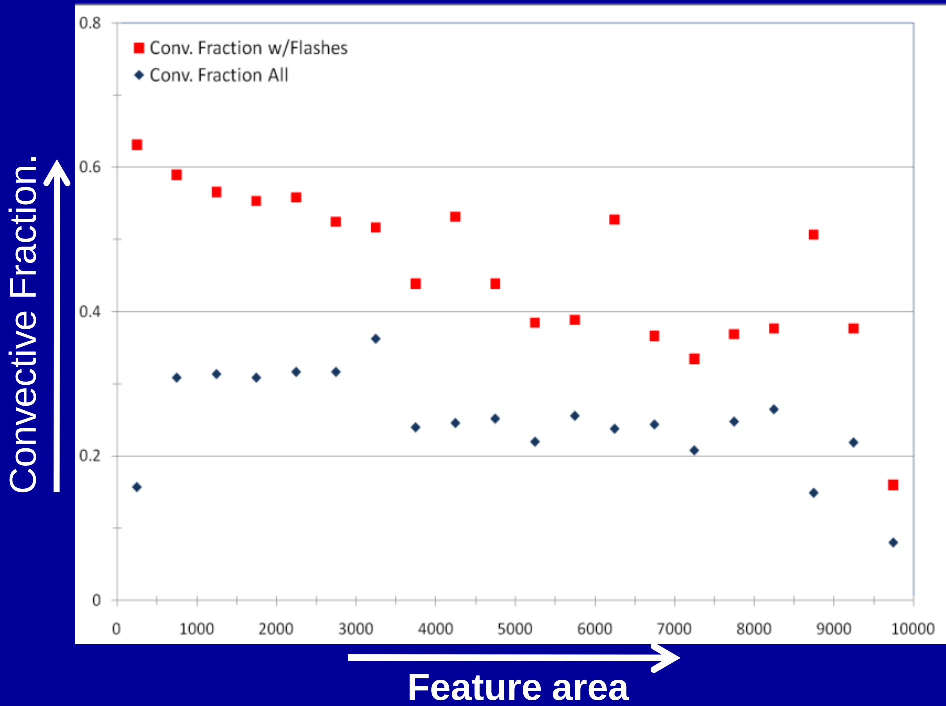
- *Focus: Presence/amount of lightning for establishing systematic differences (e.g., constraints) in cloud-system-wide C/S precipitation and/or SCaMPR cloud ID behavior*

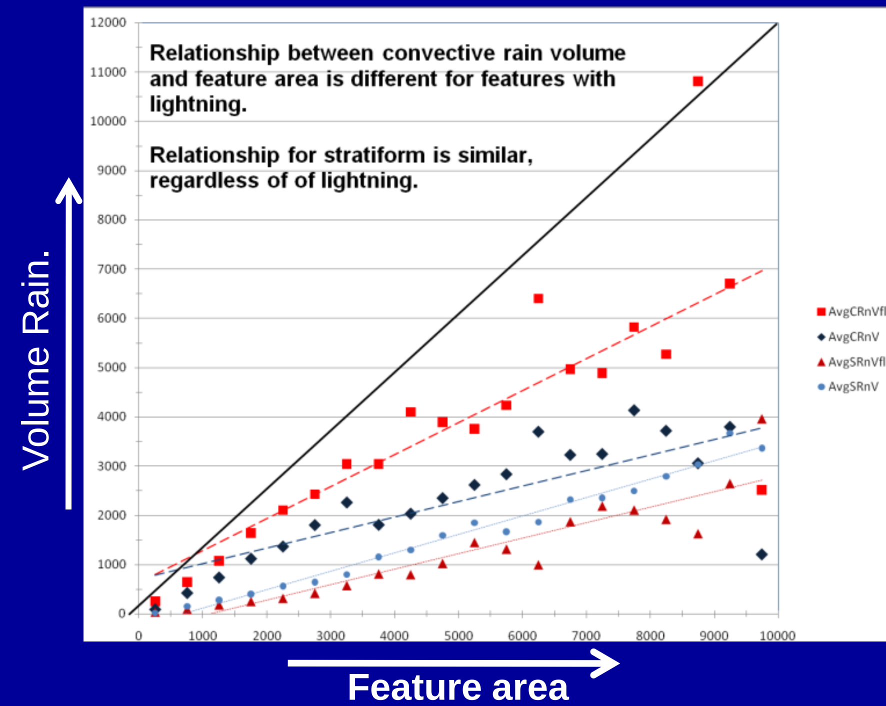
- ***Assume you could identify "cells"……….***

2) Interim "cell-scale" guidance for Passive microwave (PMW) "Calibrator"

- Land focus where PMW algorithms are driven by assumed ice-scattering relationship to rain water content
- When is there "enough" coupling between rain, ice phase, lightning to improve PMW or provide tuning when no PMW exists?
- *Focus: Cell-scale (location specific) and regime behavior of thunderstorms viewed with PMW and LIS (i.e., detected lightning production) relevant to fine tuning IR/PMW calibration.*

Identifying Systematic C/S behavior in TRMM Features





For a given feature area:

- **When lightning present, *clear increase in convective area-fraction and convective rain volume.***
- **Stratiform behavior virtually identical between lightning/non-lightning case**

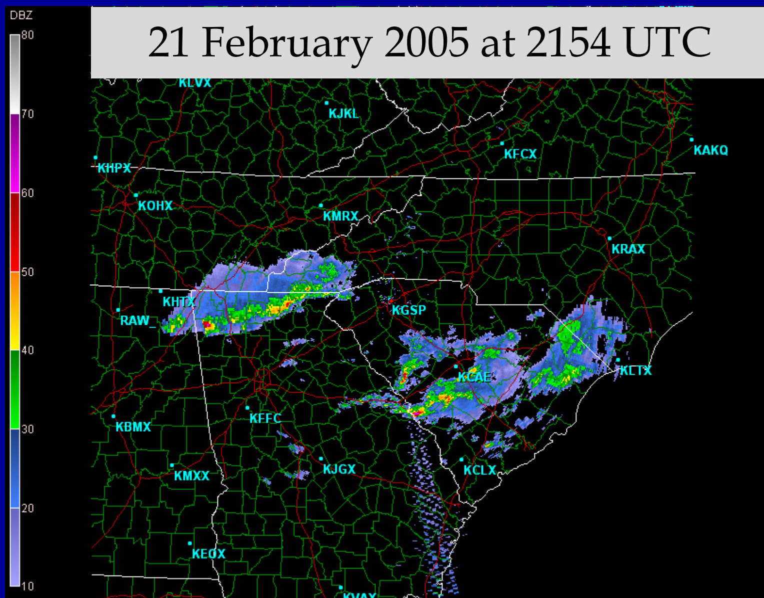
Implication: Benefit to knowing *both* lightning and C/S property.

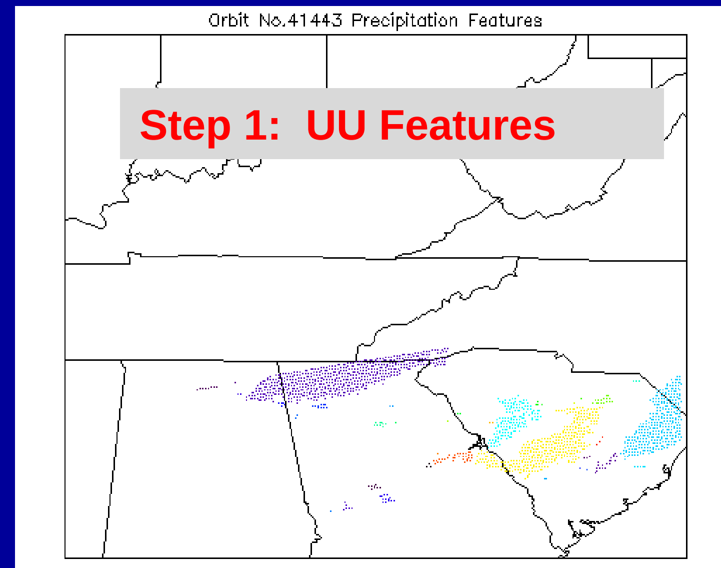
"Thorns":

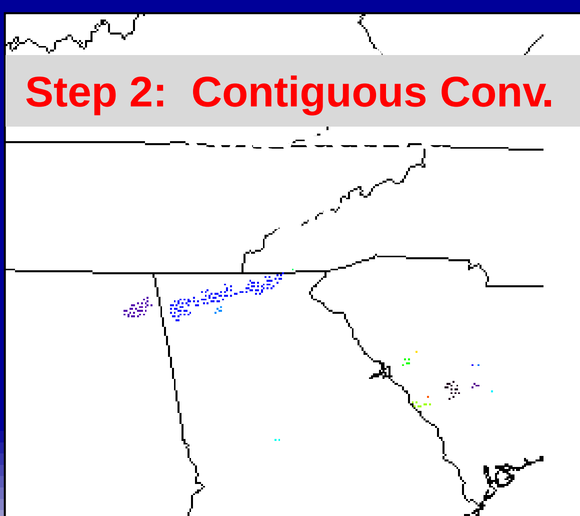
- **Lifecycle bias? Need to verify with ground based datasets (radar + C/S + LMA)**
- **Features are a "blurry" way to do the job. Need to do things on finer (cell) scales and take advantage of "locating" capability of lightning information.**

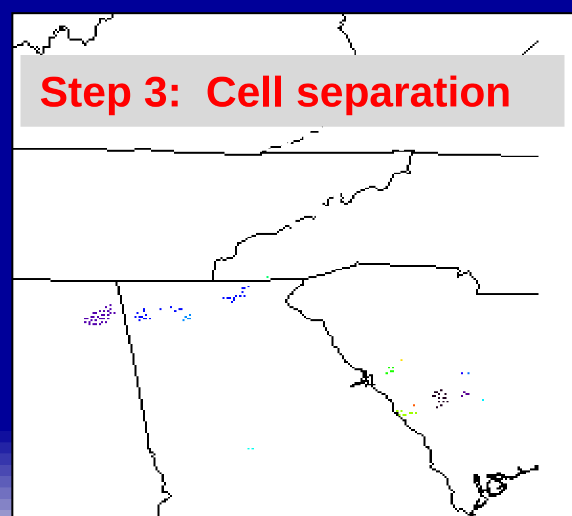
Focus on cells: Developing a TRMM Cell Database

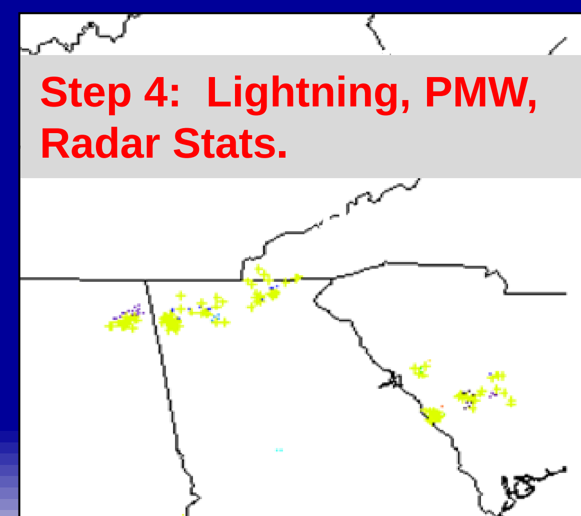
Implicit: Where there is lightning….there is a cell producing rain, ice and PMW signatures: Focus on these cells.



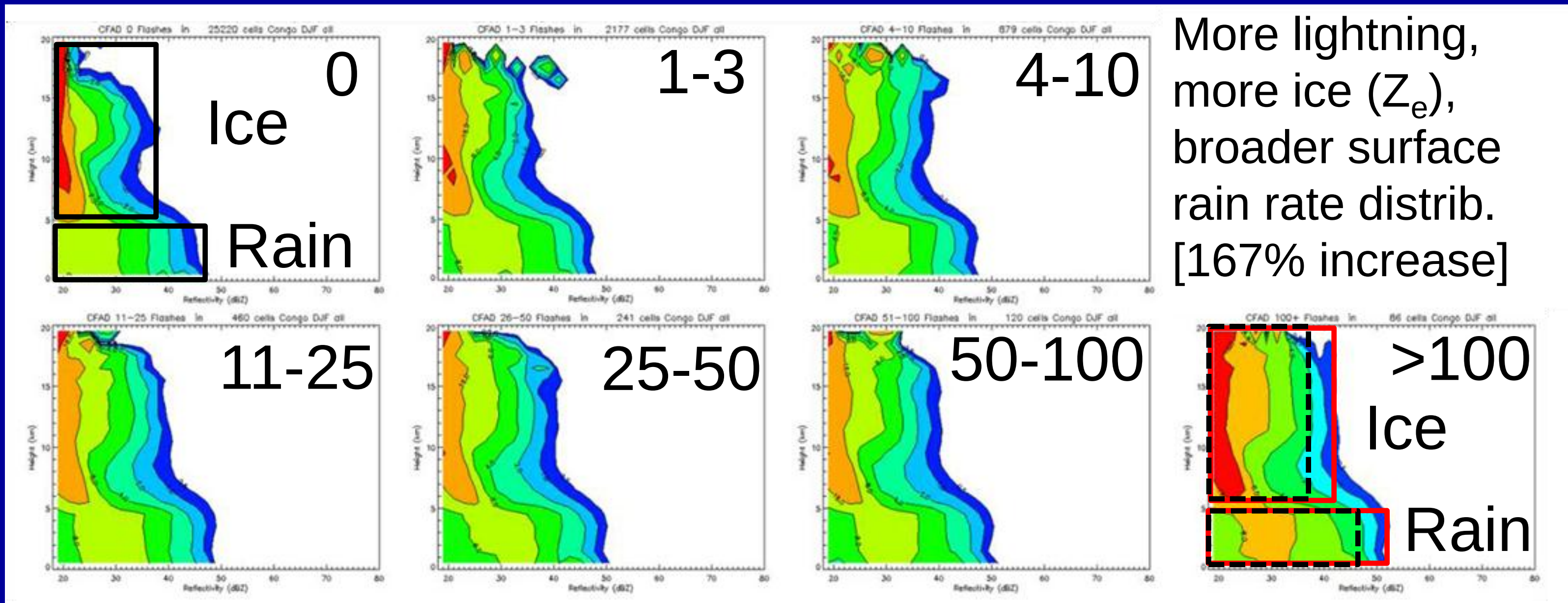








Convective Cell CFADs: TRMM PR, Congo

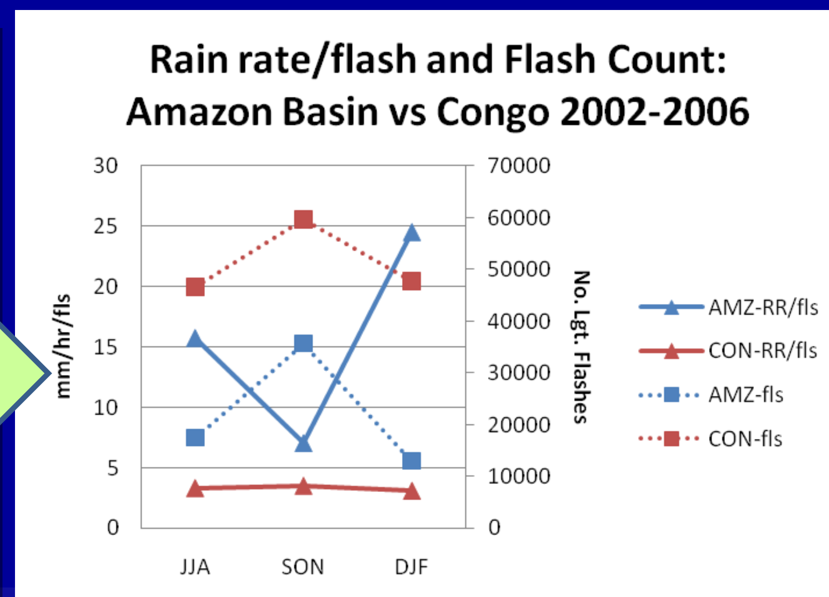


More lightning, more ice (Z_e), broader surface rain rate distrib. [167% increase]

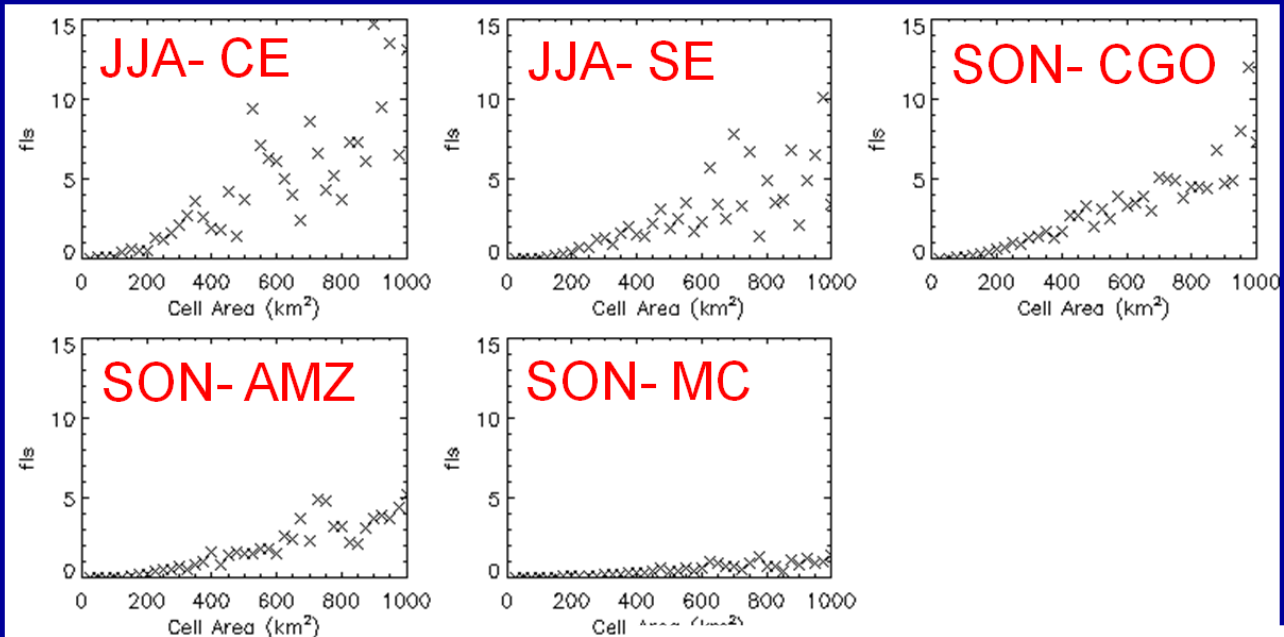
For ***regimes with ice process control of the rain rate spectrum-*** may be some hope to use lightning at cell-scales (even qualitatively) as a rainfall proxy [hence Congo focus]

One characteristic to look for- a constant or approximately invariant rain-yield (environment impact on coupling)

Regime behavior may also be a useful diagnostic for tuning satellite QPE algorithm



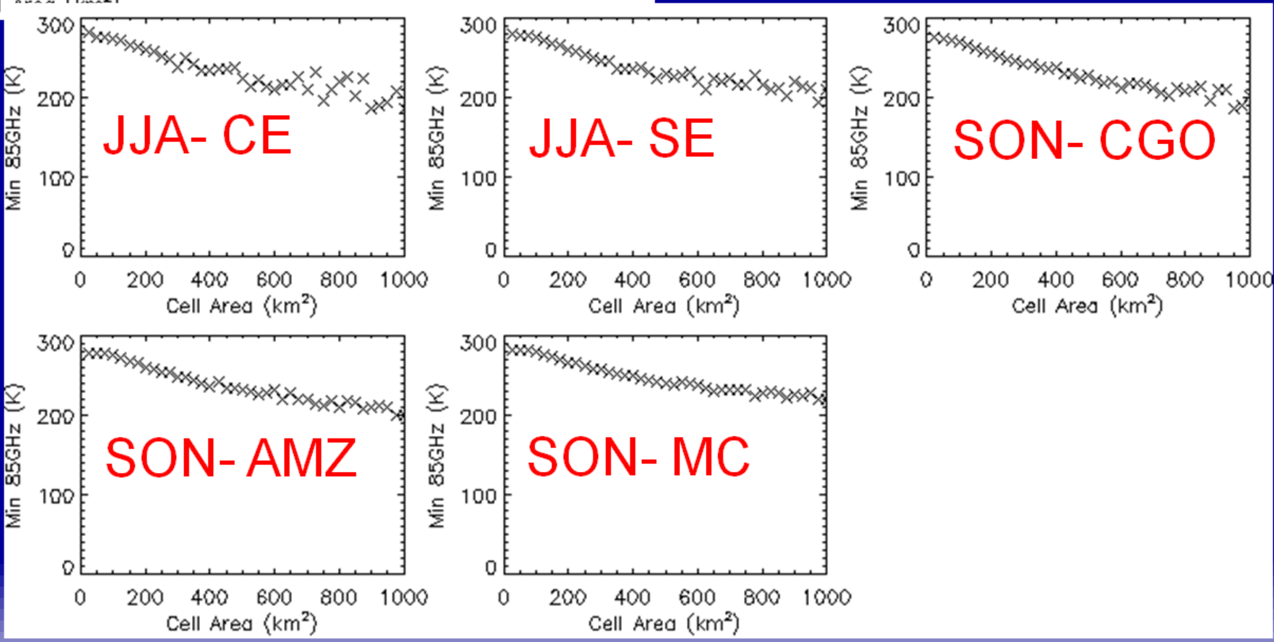
Characteristic Cell Flash Counts and 85 TB Min



From LEO, given a cell size, what is the “expected” flash count?

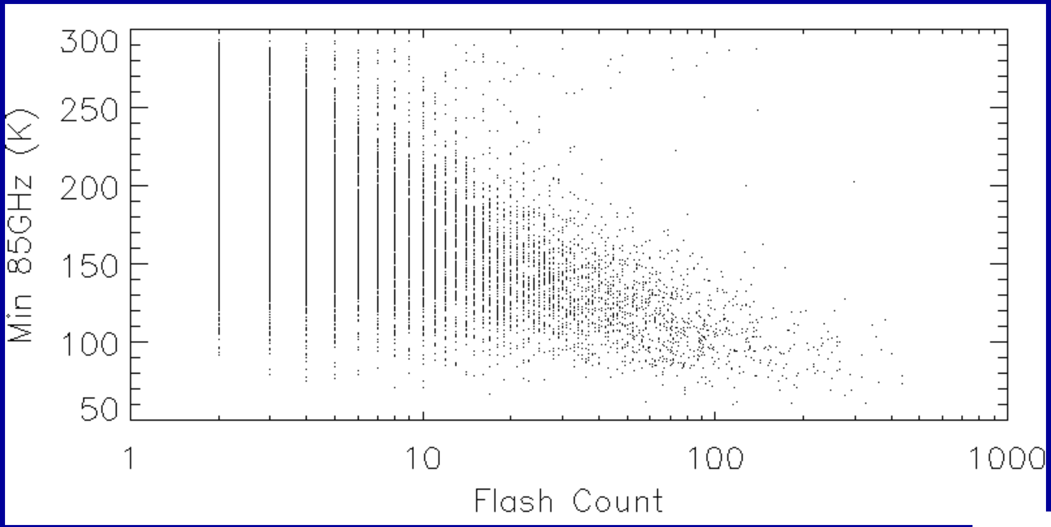
Given a cell size, what is the “expected” minimum 85 GHz TB?

Obvious limitation is LEO- but this is the PMW tuning provided



Cell Min 85GHz TB vs Flash Count

- Composite of JJA-CE, JJA-SE, SON-CON, SON-AMZ, SON-MC



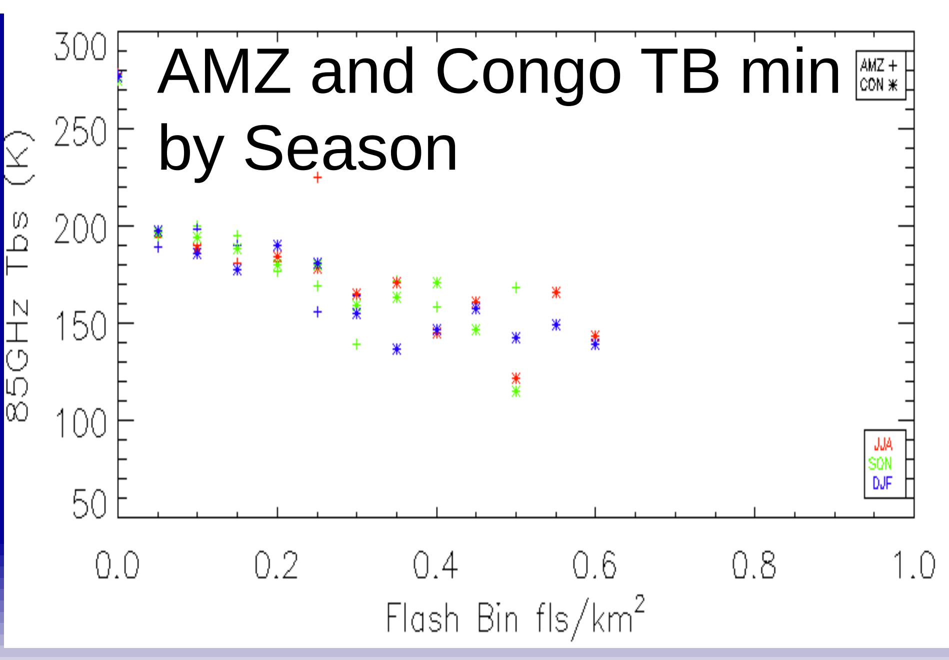
Noisy, but clear trend in minimum 85 TB and cell flash count (as expected, historically)

Regime?

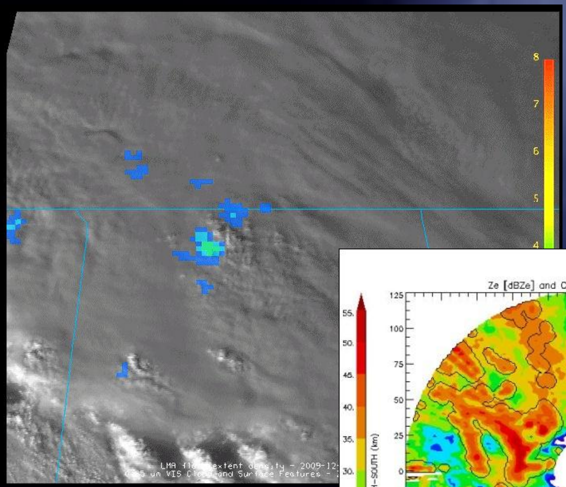
Cleaned up: AMZ and Congo by seasonal regime

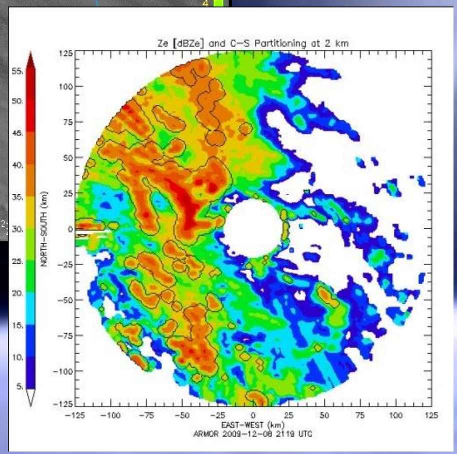
The "filtered" 85 GHz PMW behavior (Ice) is fairly robust:

- **Good thing in terms of a potential "proxy" for 85 GHz**
- **GLM An IR "tuning" parameter for QPE?**

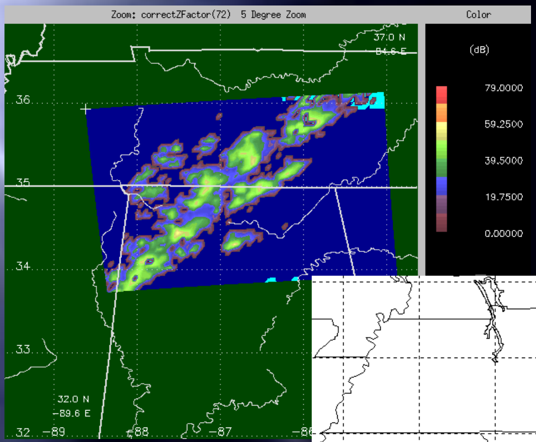


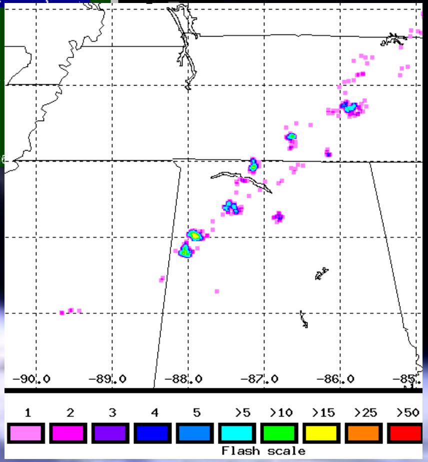
Moving Forward……..





Rapid scan + Ground Val.





LEO Lightning + Radar + PMW Datasets

- **Effort 1:** Convective Partitioning (Sat. only): Been done….can be improved
- **Effort 2:** *A priori Convective Cell* statistics (Bayesian data base) as related to GLM (LIS/Proxy flash/areas), IR, PMW (85 and 37), rain rate: Underway. Continue a QPE research collaboration with NASA-GPM
- **Effort 3:** Parallel SCaMPR algorithm for easy testing of algorithm insertion mechanics, approaches, and impact assessment.

GOES-R3 FY2010 New Start

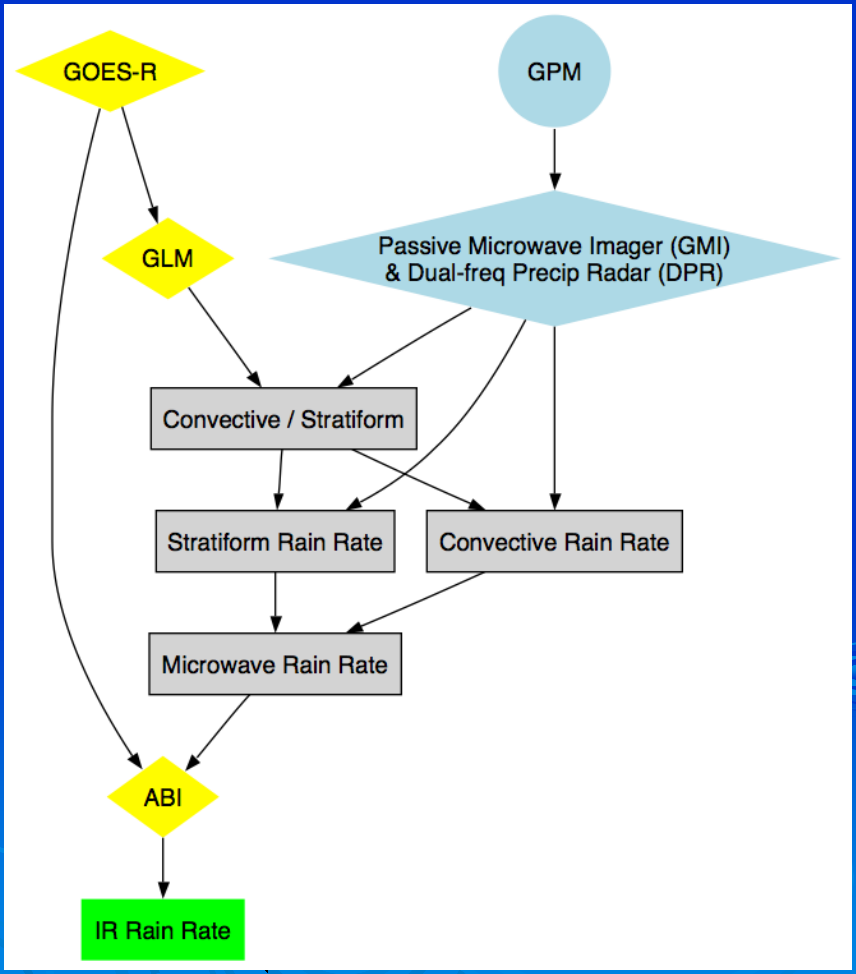
Combining GOES-R and GPM to improve GOES-R rainrate product

Nai-Yu Wang, University of Maryland, CICS
Kaushik Gopalan, University of Maryland, CICS
Rachel Albrecht, INPE, Brazil
Eric Bruning, Texas Tech University
Robert Kuligowski, NOAA/NESDIS/STAR
Ralph Ferraro, NOAA/NESDIS/STAR

Motivation

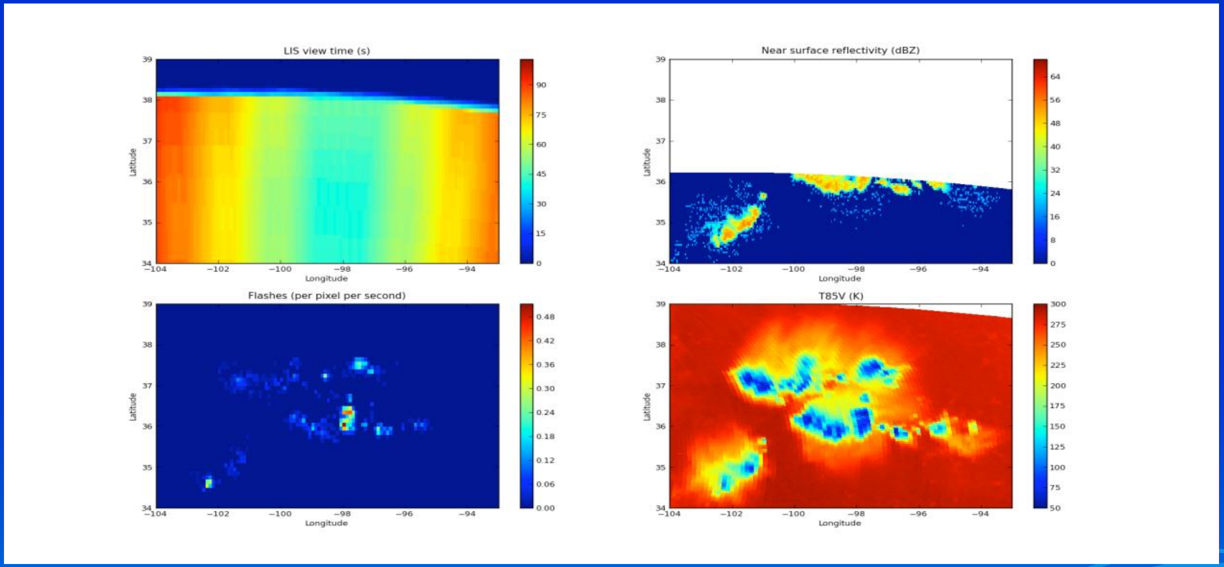
- Multi-platform and multi-sensor synergy of combining GOES-R and GPM to improve precipitation products
  - (1) To improve microwave-based precipitation by connecting the ice-phased microphysics commonly observed by GOES-R lighting and GPM microwave instruments.
  - (2) To provide GOES-R QPE algorithm:

    Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) (Kuligowski, 2002)

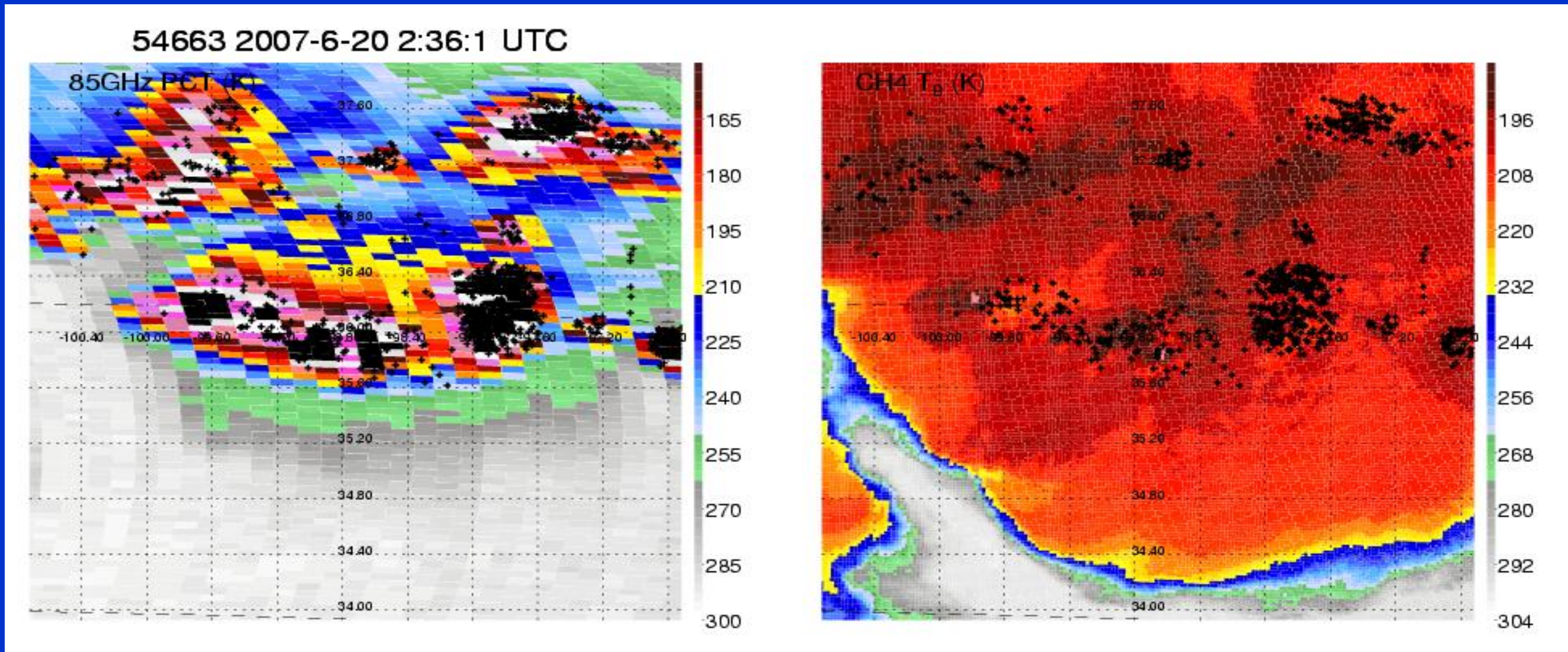


Strong Lightning and microwave 85 GHz Correlation

- The extent of the cellular features in T85V and flash centroid density correspond well to one another, while the variability in flash rate from cell-to-cell may provide added information about the intensity of convection which is a contributing factor to rain rate.



Base data from 20 June 2007. LIS total view time (upper left), and flash centroid density (lower left) are at 0.1 x 0.1 degree resolution. Near surface reflectivity from PR (upper right) and TMI vertically polarized 85 GHz brightness temperature (lower right) are from the University of Utah level 1 collocation product set.



TRMM TMI 85GHz PCT+ LIS flashes

TRMM VIRS 10.8 μm + LIS flashes

- Observations suggest lightning and PMW both respond to ice-phase particles
- PMW utilizes ice scattering signals to relate to surface rain rate over land
- How do we use the lightning data to improve the PMW rain rate by better defining convective v.s. non-convective rain type ?

Review of Lightning and Precipitation Previous Work

- Rain rate estimation using Infrared (IR) channels and Lightning Location Systems (LLS – cloud-to-ground (CG) lightning):
  - Grecu et al. (2000) showed a reduction of about 15% in the root-mean-square error of the estimates of rain volumes from IR data defined by convective areas associated by lightning.
  - Morales and Anagnostou (2003) showed that the incorporation of CGs in the rainfall type segregation ~8% the rain accumulation and 31% in the rain area when estimating rain rates from IR.
- Investigation of Precipitation Features (PF) from TRMM platform combining TMI, PR and LIS (total lightning):
  - Blyth et al. (2001), Petersen et al. (2005) and Latham et al. (2007) found that precipitation-sized ice scattering is prerequisite for lightning
  - Toracinta et al. (2002) pointed out that PF over land with lightning occupy broader brightness temperature ranges and attain a greater degree of ice scattering (lower 85 and 37 GHz temperatures) than their tropical oceanic counterparts.
  - Nesbittt et al. (2001) and Blyth et al. (2001) found that thunderstorms with highest frequency of lightning have the most pronounced microwave scattering signatures, and a log-linear relationship was shown to exist between the number of optical lightning “groups” produced of each storm and the 85 and 37 GHz brightness temperatures.
  - Boccippio (2005) showed that the combination of ice water path (retrieved from TMI) and lightning occurrence within 15 km from the center of the column cloud separated the “ambiguous” midlevel convective/stratiform cluster pairs in their lightning probabilities. This demonstrate how lightning information might statically (and expectedly) help to remove convective/stratiform ambiguity in passive microwave observations.
  - Boccipio et al. (2005) combined TMI and LIS to retrieve PR rain rates using a neural network technique. This technique improved in 10% the retrieval of convective precipitation, and up to 20% the retrieval of other PR variables, such as ice water content and probability of hail.

Convective/Stratiform Rain in Lightning and Microwave

- Boccippio et al. (2005) showed lightning might statistically help to remove convective/stratiform ambiguity in passive microwave precipitation observation

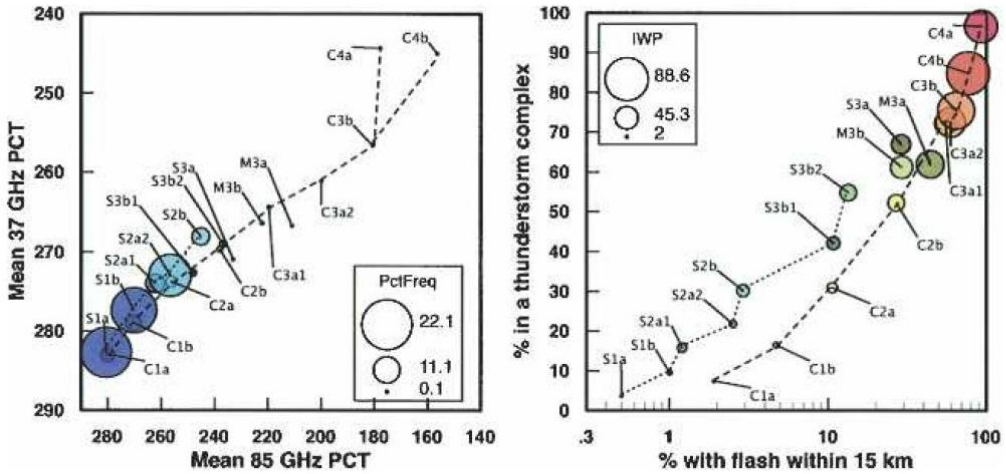
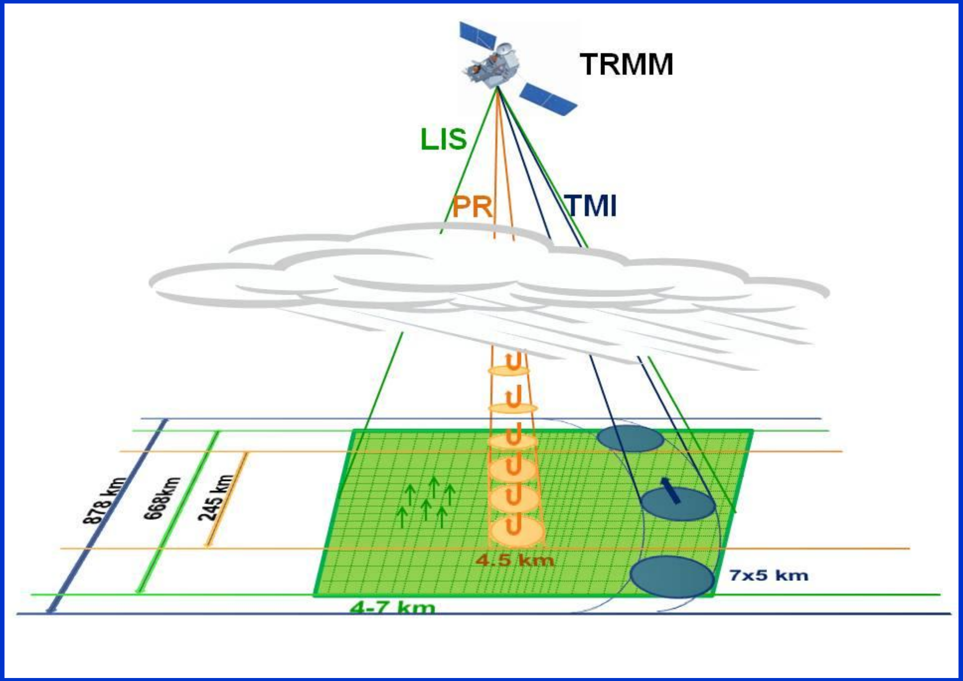


FIG. 15. High-frequency passive microwave and lightning characteristics of the profile clusters. (a) Mean 37- and 85-GHz PCT (bubble size denotes profile frequency in the entire dataset), illustrating significant convective/stratiform ambiguity for important midlevel profiles. (b) Probability that a profile of each type has an LIS-observed lightning flash centroid within 15 km and probability that a profile of each type occurs anywhere in a thunderstorm complex (1Z99 precipitation feature containing lightning). Bubble size denotes IWP, proxied by the 37–85-GHz PCT difference.

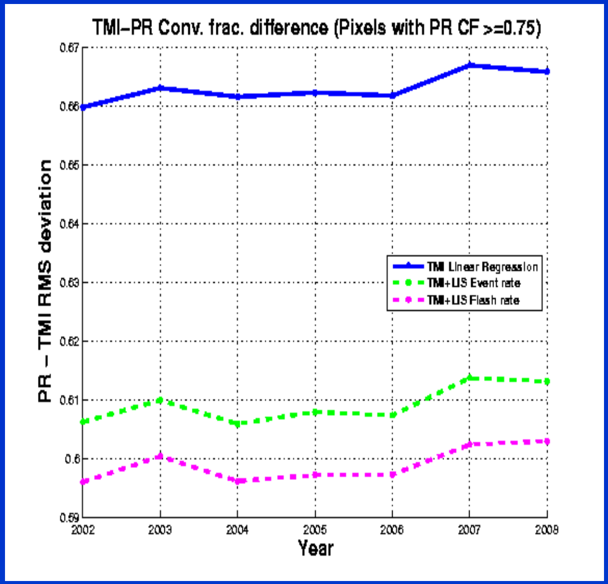
Proxy data : TRMM LIS/TMI/PR Database

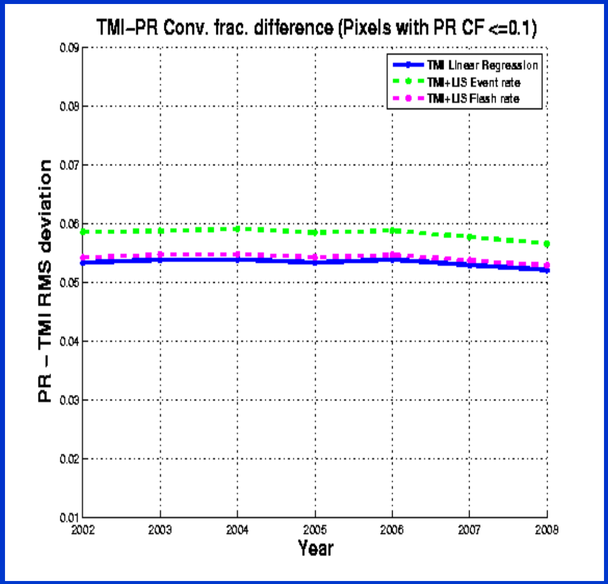


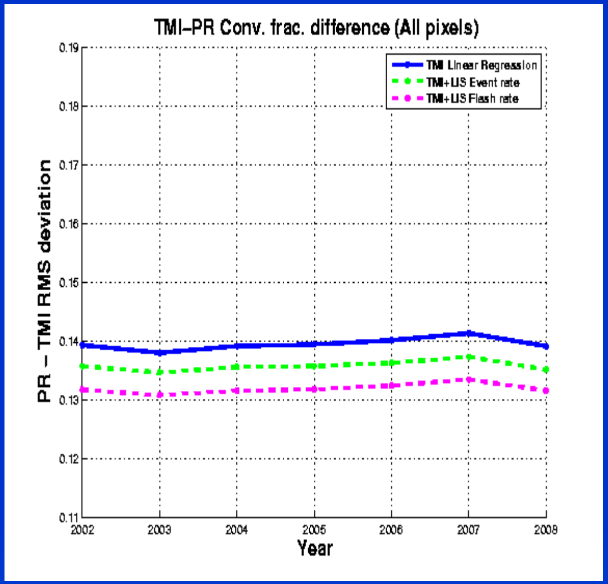
- Seven years (2002-2008) of TRMM radar/radiometer/lightning data at 0.1° grid resolution
  - PR Convective fraction estimates
  - TMI convective fraction estimate (using 19/37/85 GHz), brightness temperatures, rain-rates (using 85 GHz)
  - LIS radiance, event rate, group rate and flash rate
- 15 million raining pixels are used to investigate correlation between lightning frequency/occurrence and convective/stratirom partition in the precipitation system observed by microwave

Result: Lightning and Microwave C/S Partition

Convective **Stratiform** **All**







- Clearly the presence of lightning is prominent in convective rain
- 10% RMS error improvement in microwave convective rain identification when using lightning data
- Virtually no improvement from lightning in C/S in stratiform rain
- Overall (all rain) 5% error reduction in microwave C/S identification with lightning data

Summary

- Preliminary analysis indicated that lightning data can help microwave convective/stratiform partition, especially over convective rain regime (10% convective, 5% overall)
- Next step is to investigate lightning data on microwave rain-rate estimates through the lightning/microwave training of the C/S partition.
- Work in progress of redoing the TRMM database at 85 GHz resolution, and adding additional parameters for analysis such as PR rain-rate/storm height and LIS flash extent density.

Questions?

Bob.Kuligowski@noaa.gov